

**CONTINUATION REISSUE PATENT APPLICATION  
TRANSMITTAL**

Attorney Docket No.: ROZMAN 30RE

First Named Inventor or Application Identifier: Allen Frank Rozman

**U.S. PTO****10/27/99**Address to: Assistant Commissioner of Patents and Trademarks  
Box Reissue Patent Application  
Washington, D.C. 20231

Express Mail Label No.: EL176028766US

Continuation Reissue Application of U.S. Patent Application Serial No.  
09/039,106

Filing Date: March 13, 1998

**APPLICATION FOR REISSUE OF:**  
*(check applicable box)*
 Utility Patent     Design Patent     Plant Patent

**APPLICATION ELEMENTS**

1. Fee Transmittal Form  
*(Submit an original, and a duplicate for fee processing)*
  
 2. Specification & Claims 12 total pages  
*(amended, if appropriate)*
  
 3. Drawing(s) 4 total pages  
*(proposed amendments, if appropriate)*
  
 4. Reissue Oath/ Declaration  
 Continuation Declaration 3 pages  
 Parent Declaration 3 pages  
*(37 CFR 1.175)(PTO/SB/51 or 52)*
  
 5. Original U.S. Patent  
 Offer to Surrender Original Patent from Parent Application 1 page  
*(37 CFR 1.178)(PTO/SB/53 or PTO/SB/54)*
  
 6. Original U.S. Patent currently assigned?  
 Yes     No  
*(if yes, check applicable box(es))*
  
 7. Written Consent of all Assignees from Parent Application  
 Assignee's Assent to Reissue 1 page  
 Supplemental Assent of the Assignee to Reissue 1 page  
 Second Supplemental Assent of the Assignee to Reissue 1 page  
*(PTO/SB/53 or 54)*
  
 8. 37 CFR 3.73(b) Statement from Parent Application  
 Certificate under 37 C.F.R. 3.73(b) 1 page  
 Supplemental Certificate under 37 C.F.R. 3.73(b) with  
 Attachments 8 pages

**ACCOMPANYING APPLICATION PARTS**

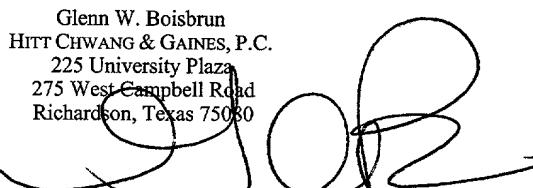
9. Transfer drawings from Patent File  
  
 10. Foreign Priority Claim (35 USC 119) (if applicable)  
  
 11. Information Disclosure Statement (IDS)/PTO-1449  
 Copies of IDS Citations  
  
 12. English Translation of Reissue Oath/Declaration (if applicable)  
  
 13. Small Entity Statement(s)  
 Statement filed in prior application, Status still  
 proper and desired.  
  
 14. Preliminary Amendment with Red-lined Drawings 17 pages  
  
 15. Return Receipt Postcard (MPEP 503)  
*(Should be specifically itemized)*  
  
 16. Other: Express Mail Certificate of Mailing

## 15. Correspondence Address

Address all future communications: (May only be completed by applicant, or attorney or agent of record)

Glenn W. Boisbrun  
 HITT CHWANG & GAINES, P.C.  
 225 University Plaza  
 275 West Campbell Road  
 Richardson, Texas 75080

Date

**10 27 99**
  
 Glenn W. Boisbrun  
 Registration No. 39,615

Address of signatory:

HITT CHWANG & GAINES, P.C.  
 225 University Plaza  
 275 West Campbell Road  
 Richardson, Texas 75080  
 (972) 480-8800  
 Fax: (972) 480-8865

- inventor(s)  
 filed under 1.34(a)  
 assignee of complete interest  
 attorney or agent of record

Atty. Docket No. ROZMAN 6

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

REISSUE APPLICATION

U.S. Patent No.: 5,528,482

Issued: June 18, 1996

Applicant: Allen Frank Rozman

Title: Low Loss Synchronous Rectifier For Application  
to Clamped-Mode Power Converters

ASSIGNEE'S ASSENT TO REISSUE

Honorable Commissioner of Patents and Trademarks  
Washington, D.C. 20231

Sir:

The undersigned Assignee is the owner of the entire interest in U.S. Patent Number 5,528,482 to Allen Frank Rozman by an Assignment that is recorded in the United States Patent and Trademark Office at Reel 7023, Frames 441-443. In accordance with the provisions of 37 C.F.R. § 1.172, the Assignee hereby consents to the filing of the accompanying reissue application and further consents to the filing of the reissue oath by the inventor thereof.

Lucent Technologies Inc.

  
By: M. R. Greene

Title: Acting President - Intellectual Property

Date: 2-25-98

Atty. Docket No. ROZMAN 6

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

REISSUE APPLICATION

U.S. Patent No.: 5,528,482

Issued: June 18, 1996

Applicant: Allen Frank Rozman

Title: Low Loss Synchronous Rectifier For Application  
to Clamped-Mode Power Converters

SUPPLEMENTAL ASSENT OF THE ASSIGNEE TO REISSUE

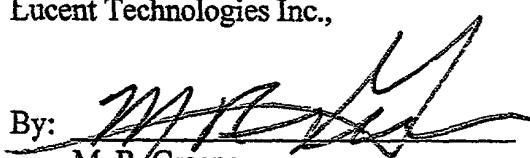
Honorable Commissioner of Patents and Trademarks  
Washington, D.C. 20231

Sir:

The undersigned Assignee is the owner of the entire interest in U.S. Patent Number 5,528,482 to Allen Frank Rozman. The right of ownership is established by virtue of an Assignment from Allen Frank Rozman to AT&T Corp. that is recorded in the United States Patent and Trademark Office at Reel 7023, Frames 441-443 and by a subsequent Assignment from AT&T Corp. to Lucent Technologies Inc. that is recorded in the United States Patent and Trademark Office at Reel 8102, Frame 0142. In accordance with the provisions of 37 C.F.R. §1.172, the Assignee hereby consents to the filing of the accompanying reissue Application and further consents to the filing of the reissue Declaration by the inventor thereof.

Lucent Technologies Inc.,

By:

  
M. R. Greene

Title: Acting President - Intellectual Property

Date: 5-29-97

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

**REISSUE APPLICATION**

U.S. Patent No.: 5,528,482  
Serial No.: 08/225,027  
Issued: June 18, 1996  
Applicant: Allen Frank Rozman  
Title: Low Loss Synchronous Rectifier For Application  
to Clamped-Mode Power Converters

**SECOND SUPPLEMENTAL ASSENT OF THE ASSIGNEE TO REISSUE**

Box: Reissue  
Honorable Commissioner of Patents and Trademarks  
Washington, D.C. 20231

Sir:

The undersigned assignee is the owner of the entire right, title and interest in U.S. Patent Number 5,528,482 to Allen Frank Rozman. In accordance with the provisions of 37 C.F.R. §1.172, the assignee hereby consents to the filing of the accompanying reissue Application and further consents to the filing of the reissue Declaration by the inventor thereof. A Certificate under 37 C.F.R. §3.73(b) is submitted herewith thereby establishing a right of the assignee to take action.

Lucent Technologies Inc.,

By: M.R. Greene

M. R. Greene

Title: Vice President - Law

Date: 1-18-99

Atty. Docket No. ROZMAN 6

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

REISSUE APPLICATION

U.S. Patent No.: 5,528,482

Issued: June 18, 1996

Applicant: Allen Frank Rozman

Title: Low Loss Synchronous Rectifier For Application  
to Clamped-Mode Power Converters

**CERTIFICATE UNDER 37 C.F.R. 3.73(b)**

Honorable Commissioner of Patents and Trademarks  
Washington, D.C. 20231

Sir:

Lucent Technologies Inc., a Delaware corporation, certifies that it is the Assignee of the entire right, title and interest in the patent application identified above by virtue of an Assignment from Allen Frank Rozman to AT&T Corp. that is recorded in the United States Patent and Trademark Office at Reel 7023, Frames 441-443 and by a subsequent Assignment from AT&T Corp. to Lucent Technologies Inc. that is recorded in the United States Patent and Trademark Office at Reel 8102, Frame 0142. The undersigned is empowered to sign this Certificate on behalf of the Assignee.

Lucent Technologies Inc.,

By: 

M. R. Greene

Title: Acting President - Intellectual Property

Date: 5-27-98

Atty. Docket No. ROZMAN 6

PATENT

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

**REISSUE APPLICATION**

U.S. Patent No.: 5,528,482  
Serial No.: 08/225,027  
Issued: June 18, 1996  
Applicant: Allen Frank Rozman  
Title: Low Loss Synchronous Rectifier For Application  
to Clamped-Mode Power Converters

**SUPPLEMENTAL CERTIFICATE UNDER 37 C.F.R. 3.73(b)**

Box: Reissue  
Honorable Commissioner of Patents and Trademarks  
Washington, D.C. 20231

Sir:

Lucent Technologies Inc., a corporation organized and existing under the laws of the State of Delaware and having its principal office at 600 Mountain Avenue, Murray Hill, New Jersey, 07974-0636, U.S.A., certifies it is the sole owner of the entire right, title and interest in the U.S. patent identified above by virtue of a chain of title from the inventor to the current assignee as set forth below.

1. Lucent Technologies Inc., is the owner by assignment of the entire right, title, and interest in the above-identified patent in a Patent Assignment Agreement recorded in the U.S. Patent and Trademark Office ("USPTO") at Reel No. 8102, Frame 0142.

2. The prior assignee, AT&T Corp., reestablished itself status quo ante as the owner of all AT&T IPM Corp. Intellectual property, including the above-identified patent, in a Rescission Agreement attached hereto (this document is the only document in the chain of title not recorded in the USPTO).

3. Prior to reestablishing itself status quo ante as the owner of the above-identified patent, AT&T Corp. agreed to transfer all right, title, and interest in its intellectual property which included the above-identified patent to AT&T IPM Corp. in an agreement recorded on Reel No. 7467, Frame 0511.

4. The prior assignee, AT&T Corp., was the owner by assignment of the entire right, title, and interest in the above-identified patent by virtue of an assignment recorded in the USPTO at Reel No. 7023, Frame 0441.

The undersigned has reviewed all the documents in the chain of title of the patent identified above and, to the best of the undersigned's knowledge and belief, title is in the assignee, Lucent Technologies Inc.

The undersigned (whose title is supplied below) is empowered to sign this Certificate on behalf of the assignee.

I hereby declare that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true; and further, that these statements are made with the knowledge that willful false statements, and the like so made, are punishable by fine or imprisonment, or both under, Section 1001, Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the patent.

Lucent Technologies Inc.,

By:   
M. R. Greene  
Title: Vice President - Law

Date: 1-18-98

Attachment: Agreement to Rescind the Assignment of Intellectual Property

Atty. Docket No. ROZMAN 30RE

PATENT

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

**CONTINUATION REISSUE APPLICATION**

U.S. Application Serial No.: 09/039,106

Applicant: Allen Frank Rozman

Title: Low Loss Synchronous Rectifier for Application to  
Clamped-Mode Power Converters

Commissioner of Patents  
and Trademarks  
Washington, D.C. 20231

Box: Reissue

Sir:

**EXPRESS MAIL CERTIFICATE OF MAILING**

I hereby certify that the foregoing items are being deposited with the United States Postal Service "Express Mail Post Office to Addressee" (Mailing Label No. EL176028766US) service under 37 C.F.R. § 1.10 on the date indicated below and is addressed to:

Commissioner of Patents  
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Washington, D.C. 20231

Box: Reissue

- Reissue Transmittal Form;
- Fee Transmittal Letter;
- Reissue Specification & Claims;
- Drawings (4 sheets);
- Continuation Reissue Declaration;
- copy of parent Reissue Declaration;
- original U.S. Patent No. 5,528,482;

- Offer to Surrender;
- Assignee's Assent to Reissue;
- Supplemental Assent of the Assignee to Reissue;
- Second Supplemental Assent of the Assignee to Reissue;
- Certificate Under 37 C.F.R. 3.73(b);
- Supplemental Certificate Under 37 C.F.R. 3.73(b) with Attachments;
- Preliminary Amendment with red-lined drawings; and
- a postcard receipt.

Date Mailed: October 27, 1999

Stephanie Stafford  
Stephanie Stafford

HITT CHWANG & GAINES P.C.  
225 University Plaza  
275 West Campbell Road  
Richardson, Texas 75080  
(972) 480-8800

DOCKET NO. ROZMAN 30RE

PATENT

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

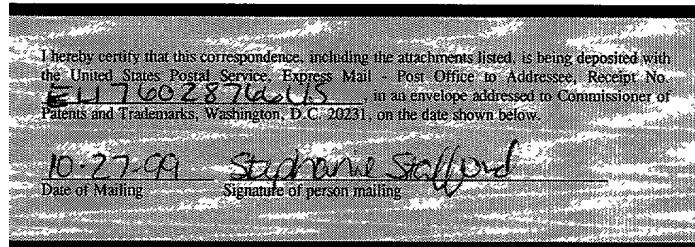
In re application of:

**ALLEN FRANK ROZMAN**

For: **LOW LOSS SYNCHRONOUS RECTIFIER FOR APPLICATION  
TO CLAMPED-MODE POWER CONVERTERS**

Commissioner of Patents  
and Trademarks  
Washington, D. C. 20231

Sir:



**PRELIMINARY AMENDMENT**

Before examination of the above-identified application, please amend it as set forth below.

**IN THE SPECIFICATION:**

Kindly amend the specification by inserting before the first line:

--This application is a continuation of reissue application Serial Number 09/039,106, filed on March 13, 1998, currently pending. The above-listed application Serial Number 09/039,106 is commonly assigned with the present invention and is incorporated herein by reference.--

**IN THE CLAIMS:**

Kindly cancel Claims 1-60 without prejudice or disclaimer.

Kindly add Claims 61-110 as follows:

--61. A method of operating a power converter, comprising:  
providing a power transformer having a plurality of windings;  
limiting a voltage across at least one of said plurality of windings with a clamping circuit  
during a clamping interval of said power converter; and  
rectifying said voltage with a synchronous rectification device having a control terminal  
responsive to a signal across at least one of said plurality of windings such that said synchronous  
rectification device is active for substantially all of said clamping interval.--

--62. The method as claimed in claim 61 wherein said clamping circuit is directly connected to said power transformer.--

--63. The method as claimed in claim 61 wherein said clamping circuit is coupled to a primary winding of said power transformer.--

--64. The method as claimed in claim 61 wherein said power transformer has a center-tapped secondary winding.--

--65. The method as claimed in claim 61 further comprising connecting a primary winding of said power transformer to an input of said power converter during a first cyclic interval of said power converter.--

--66. The method as claimed in claim 61 further comprising a further synchronous rectification device, coupled to said power transformer, that is active during a first cyclic interval of said power converter.--

--67. The method as claimed in claim 61 further comprising a rectification device, coupled to said power transformer, that is active during a first cyclic interval of said power converter.--

--68. The method as claimed in claim 61 wherein said clamping circuit comprises a switching device connected in series with a capacitor.--

--69. The method as claimed in claim 68 further comprising controlling said switching device with a control circuit.--

--70. The method as claimed in claim 61 wherein said power converter operates in one of:

a forward mode,  
a flyback mode, and  
a forward/flyback mode.--

--71. A method of operating a power converter, comprising:  
providing a power transformer having a plurality of windings;  
coupling a synchronous rectification device, having a control terminal, to at least one of said plurality of windings;  
coupling a clamping circuit to said at least one of said plurality of windings; and  
limiting a voltage applied to said control terminal with said clamping circuit such that said synchronous rectification device is active for substantially all of a clamping interval.--

--72. The method as claimed in claim 71 wherein said clamping circuit is directly connected to said power transformer.--

--73. The method as claimed in claim 71 wherein said clamping circuit is coupled to a primary winding of said power transformer.--

--74. The method as claimed in claim 71 wherein said power transformer has a center-tapped secondary winding.--

--75. The method as claimed in claim 71 further comprising connecting a primary winding of said power transformer to an input of said power converter during a first cyclic interval of said power converter.--

--76. The method as claimed in claim 71 further comprising a further synchronous rectification device, coupled to said power transformer, that is active during a first cyclic interval of said power converter.--

--77. The method as claimed in claim 71 further comprising a rectification device, coupled to said power transformer, that is active during a first cyclic interval of said power converter.--

--78. The method as claimed in claim 71 wherein said clamping circuit comprises a switching device connected in series with a capacitor.--

--79. The method as claimed in claim 78 further comprising controlling said switching device with a control circuit.--

--80. The method as claimed in claim 71 wherein said power converter operates in one of:

- a forward mode,
- a flyback mode, and
- a forward/flyback mode.--

--81. A method of operating a power converter, comprising:  
providing a power transformer having a plurality of windings;  
coupling a synchronous rectification device, having a control terminal, to at least one of  
said plurality of windings;  
coupling a clamping circuit to said at least one of said plurality of windings; and  
limiting a voltage applied to said control terminal with said clamping circuit such that said  
synchronous rectification device conducts a load current for substantially all of a clamping  
interval.--

--82. The method as claimed in claim 81 wherein said clamping circuit is directly  
connected to said power transformer.--

--83. The method as claimed in claim 81 wherein said clamping circuit is coupled to a primary winding of said power transformer.--

--84. The method as claimed in claim 81 wherein said power transformer has a center-tapped secondary winding.--

--85. The method as claimed in claim 81 further comprising connecting a primary winding of said power transformer to an input of said power converter during a first cyclic interval of said power converter.--

--86. The method as claimed in claim 81 further comprising a further synchronous rectification device, coupled to said power transformer, that is active during a first cyclic interval of said power converter.--

--87. The method as claimed in claim 81 further comprising a rectification device, coupled to said power transformer, that is active during a first cyclic interval of said power converter.--

--88. The method as claimed in claim 81 wherein said clamping circuit comprises a switching device connected in series with a capacitor.--

--89. The method as claimed in claim 88 further comprising controlling said switching device with a control circuit.--

--90. The method as claimed in claim 81 wherein said power converter operates in one of:

- a forward mode,
- a flyback mode, and
- a forward/flyback mode.--

--91. A method of operating a power converter, comprising:  
providing a power transformer having a plurality of windings;  
coupling a synchronous rectification device, having a control terminal responsive to a drive signal, to at least one of said plurality of windings;  
coupling a clamping circuit to said at least one of said plurality of windings; and  
limiting said drive signal applied to said control terminal with said clamping circuit such that said drive signal is continuous for substantially all of a clamping interval.--

--92. The method as claimed in claim 91 wherein said clamping circuit is directly connected to said power transformer.--

--93. The method as claimed in claim 91 wherein said clamping circuit is coupled to a primary winding of said power transformer.--

--94. The method as claimed in claim 91 wherein said power transformer has a center-tapped secondary winding.--

--95. The method as claimed in claim 91 further comprising connecting a primary winding of said power transformer to an input of said power converter during a first cyclic interval of said power converter.--

--96. The method as claimed in claim 91 further comprising a further synchronous rectification device, coupled to said power transformer, that is active during a first cyclic interval of said power converter.--

--97. The method as claimed in claim 91 further comprising a rectification device, coupled to said power transformer, that is active during a first cyclic interval of said power converter.--

--98. The method as claimed in claim 91 wherein said clamping circuit comprises a switching device connected in series with a capacitor.--

--99. The method as claimed in claim 98 further comprising controlling said switching device with a control circuit.--

--100. The method as claimed in claim 91 wherein said power converter operates in one of:

- a forward mode,
- a flyback mode, and
- a forward/flyback mode.--

--101. A method of operating a power converter, comprising:  
accepting a DC voltage at an input of said power converter;  
providing current to a load coupled to an output of said power converter;  
transforming a voltage from said input to said output with a power transformer having at least one primary winding and at least one secondary winding;  
periodically connecting said input to said at least one primary winding during a first cyclic interval of said power converter;  
limiting said voltage across said at least one secondary winding with a clamping circuit during a clamping interval of said power converter; and  
rectifying said voltage with a synchronous rectification device having a control terminal responsive to a signal across said at least one secondary winding such that said synchronous rectification device is active for substantially all of said clamping interval.--

--102. The method as claimed in claim 101 wherein said clamping circuit is directly connected to said power transformer.--

--103. The method as claimed in claim 101 wherein said clamping circuit is coupled to said at least one primary winding of said power transformer.--

--104. The method as claimed in claim 101 wherein said at least one secondary winding has a center-tap.--

--105. The method as claimed in claim 101 further comprising a voltage limiting device coupled to said synchronous rectification device.--

--106. The method as claimed in claim 101 further comprising a further synchronous rectification device, coupled to said power transformer, that is active during a first cyclic interval of said power converter.--

--107. The method as claimed in claim 101 further comprising a rectification device, coupled to said power transformer, that is active during a first cyclic interval of said power converter.--

--108. The method as claimed in claim 101 wherein said clamping circuit comprises a switching device connected in series with a capacitor.--

--109. The method as claimed in claim 108 further comprising controlling said switching device with a control circuit.--

of:

- a forward mode,
- a flyback mode, and
- a forward/flyback mode.--

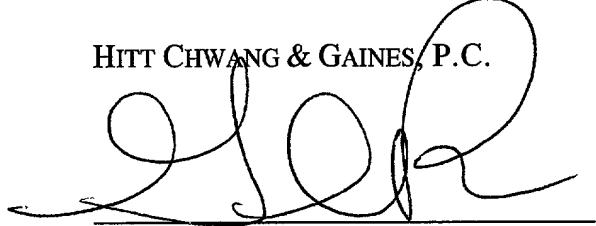
## **REMARKS**

The Applicant respectfully submits that the foregoing claims are allowable. Therefore, a Notice of Allowance for Claims 61-110 is respectfully requested. The Applicant also submits herewith a red-lined set of figures identifying the amended figures as "amended" in compliance with 37 C.F.R. § 1.121.

Should it facilitate allowance of the application, the Examiner is invited to telephone the undersigned attorney. The Commissioner is hereby authorized to charge any additional payment that may be due or credit any overpayment to Deposit Account No. 12-2325.

Respectfully submitted,

HITT CHWANG & GAINES, P.C.



Glenn W. Boisbrun  
Registration No. 39,615

Date: 10/27/99

225 University Plaza  
275 West Campbell Road  
Richardson, Texas 75080  
(972) 480-8800

LOW LOSS SYNCERONOUS RECTIFIER  
FOR APPLICATION TO CLAMPED-MODE  
POWER CONVERTERS

This application is a [continuation in part] continuation of application Ser. No. 08/054,918 filed on Apr. 29, 1993 now issued as U.S. Pat. No. 5,303,138 on Apr. 12, 1994

FIELD OF THE INVENTION

This invention relates to switching type power converters and in particular to forward and flyback converters having a clamp-mode topology.

BACKGROUND OF THE INVENTION

Self synchronized rectifiers refer to rectifiers using MOSFET rectifying devices having control terminals which are driven by voltages of the windings of the power transformer in order to provide the rectification of the output of the transformer. Use of synchronous rectifiers has been limited however by the inefficiency of these rectifiers in buck derived converter topologies. Efficiency is limited due to the nature of switching of buck derived converters (i.e buck, buck-boost, boost converters including forward and flyback topologies) and due to the variability of the transformer reset voltages in the forward type converters. This variability of reset voltage limits the conduction time of one of the MOSFET rectifiers, diminishing the effectiveness and efficiency of the rectifier. This is because the rectifying devices do not conduct for the full switching period and the gate drive energy of one of the rectifiers is dissipated.

SUMMARY OF THE INVENTION

A synchronous rectifier is combined with a clamped-mode buck derived power converter. In one illustrative embodiment a hybrid rectifier includes a MOSFET rectifying device active in a first cyclic interval of the conduction/nonconduction sequence of the power switch. A second rectifying device embodied in one illustrative embodiment as a low forward voltage drop bipolar diode rectifying device is active during an alternative interval to the first conduction/nonconduction interval. The gate drive to the MOSFET device is maintained continuous at a constant level for substantially the all of the second interval by the clamping action of the clamping circuitry of the converter. This continuous drive enhances the efficiency of the rectifier.

The bipolar rectifier device may also be embodied as a MOSFET device in a rectifier using two MOSFET devices. The subject rectifier may be used in both forward and flyback power converters.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic of a forward converter, of the prior art, having a synchronous rectifier;

FIG. 2 is a voltage waveform of the secondary transformer winding of the converter of FIG. 1;

FIG. 3 is a schematic of a clamped-mode forward converter with a synchronous rectifier embodying the principles of the invention;

FIG. 4 is a voltage waveform of the secondary transformer winding of the converter of FIG. 3;

FIG. 5 is a schematic of another version of a clamped-mode forward converter with a synchronous rectifier embodying the principles of the invention;

FIG. 6 is a schematic of another version of a clamped-mode forward converter with a synchronous rectifier and a center tapped secondary winding embodying the principles of the invention;

5 FIG. 7 is a schematic of a clamped-mode flyback converter with a synchronous rectifier embodying the principles of the invention; and

10 FIG. 8 is a schematic of another version of a clamped-mode forward converter with a synchronous rectifier and a center tapped secondary winding embodying the principles of the invention.

#### DETAILED DESCRIPTION

15 In the converter shown in the FIG. 1, a conventional forward topology of the prior art with an isolating power transformer is combined with a self synchronized synchronous rectifier. In such a rectifier controlled devices are used with the control terminals being driven by an output winding  
20 of the power transformer.

A DC voltage input  $V_{in}$  at input 100, is connected to the primary winding 110 of the power transformer by a MOSFET power switch 101. The secondary winding 102 is connected to an output lead 103 through an output filter inductor 104 and a synchronous rectifier including the MOSFET rectifying devices 105 and 106. Each rectifying device includes a body diode 108 and 107, respectively.

With the power switch 101 conducting, the input voltage is applied across the primary winding 110. The secondary winding 102 is oriented in polarity to respond to the primary voltage with a current flow through the inductor 104, the load connected to output lead 103 and back through the MOSFET rectifier 106 to the secondary winding 102. Continuity of current flow in the inductor 104, when the power switch 101 is non-conducting, is maintained by the current path provided by the conduction of the MOSFET rectifier 105. An output filter capacitor 111 shunts the output of the converter.

40 Conductivity of the MOSFET rectifiers is controlled by the gate drive signals provided by the voltage appearing across the secondary winding 102. This voltage is shown graphically by the voltage waveform 201 in FIG. 2. During the conduction interval  $T_1$  of the power switch 101, the secondary winding voltage  $V_{as1}$  charges the gate of MOSFET 106 to bias it conducting for the entire interval  $T_1$ . The MOSFET 105 is biased non conducting during the  $T_1$  interval. The conducting MOSFET rectifying device 106 provides the current path allowing energy transfer to the output during the interval  $T_1$ . The gate of MOSFET rectifier 106 is charged in response to the input voltage  $V_{in}$ . All of the gate drive energy due to this voltage is dissipated.

As the power MOSFET switch 101 turns off, the voltage  $V_{as1}$  across the secondary winding 102 reverses polarity just 55 as the time interval  $T_2$  begins. This voltage reversal initiates a reset of the transformer magnetizing inductance, resonantly discharges the gate of MOSFET rectifier 106 and begins charging the gate of MOSFET rectifier 105. As shown by the voltage waveform of FIG. 2, the voltage across 60 the secondary winding 102 is not a constant value, but is rather a variable voltage that collapses to zero in the subsequent time interval  $T_3$ , which occurs prior to the subsequent conduction interval of the power switch 101. This voltage is operative to actually drive the rectifier 105 conducting over only a portion of the time interval  $T_2$  which is indicated by the cross hatched area 202 associated with the waveform 201 in FIG. 2. This substantially diminishes the

performance of the rectifier 105 as a low loss rectifier device. This is aggravated by the fact that the body diode 108 of the rectifier 105 has a large forward voltage drop which is too large to efficiently carry the load current.

The loss of efficiency of the synchronous rectifier limits the overall efficiency of the power converter and has an adverse effect on the possible power density attainable. Since the synchronous rectifier 105 does not continuously conduct throughout the entire switching period, a conventional rectifier diode (e.g. connected in shunt with rectifier 105) capable of carrying the load current is required in addition to MOSFET rectifier 105. This inefficiency is further aggravated by the gate drive energy dissipation associated with the MOSFET rectifier 106. This gate drive loss may exceed the conduction loss for MOSFET rectifier 106, at high switching frequency (e.g. >300 kHz).

The efficiency of a forward converter with synchronous rectification is significantly improved according to the invention by using a clamp circuit arrangement to limit the reset voltage and by using a low forward voltage drop diode in the rectifying circuitry. Such an arrangement is shown in the schematic of FIG. 3. In this forward power converter the power MOSFET device 101 is shunted by a series connection of a clamp capacitor 321 and a MOSFET switch device 322. The conducting intervals of power switch 101 and MOSFET device 322 are mutually exclusive. The duty cycle of power switch 101 is D and the duty cycle of MOSFET device 322 is 1-D. The voltage inertia of the capacitor 321 limits the amplitude of the reset voltage appearing across the magnetizing inductance during the non conducting interval of the MOSFET power switch 101.

The diode 323 of the synchronous rectifier, shown in FIG. 3, has been substituted for the MOSFET device 106 shown in the FIG. 1. Due to the dissipation of gate drive energy the overall contribution of the MOSFET rectifier 106 in FIG. 1 is limited. The clamping action of the clamping circuitry results in the constant voltage level 402 shown in the voltage waveform 401, across the secondary winding 102, in the time period  $T_2$ . This constant voltage applied to the gate drive of the MOSFET rectifier 105 drives it into conduction for the entire  $T_2$  reset interval. In this arrangement there is no need for a bipolar or a body diode shunting the MOSFET rectifier 105. An advantage in the clamped mode converter is that the peak inverse voltage applied to the diode 323 is much less than that applied to the similarly positioned MOSFET device in FIG. 1. Accordingly the diode 323 may be a very efficient low voltage diode which may be embodied by a low voltage diode normally considered unsuitable for rectification purposes.

In the operation of the clamped mode forward converter the MOSFET switch 322 is turned off just prior to turning the MOSFET power switch on. Energy stored in the parasitic capacitances of the MOSFET switching devices 101 and 322 is commutated to the leakage inductance of the power transformer, discharging the capacitance down toward zero voltage. During the time interval  $T_3$  shown in FIG. 4, voltage across the primary winding is supported by the leakage inductance. The voltage across the secondary winding 102 drops to zero value as shown in the FIG. 4. With this zero voltage level of the secondary winding, the output inductor resonantly discharges the gate capacitance of the MOSFET rectifying device 105 and eventually forward biases the bipolar diode 323. The delay time  $T_3$  is a fixed design parameter and is a factor in the control of the power switches 101 and 322, which may be switched to accommodate soft waveforms. This synchronous rectification circuit of FIG. 3 provides the desired efficiencies lacking in the arrangement of the circuit shown in FIG. 1.

Control of the conductivity of the power switching devices 101 and 322 is by means of a control circuit 350, which is connected, by lead 351, to an output terminal 103 of the converter to sense the output terminal voltage. The control circuit 350 is connected, by leads 353 and 354, to the drive terminals of the power switches 101 and 322. The drive signals are controlled to regulate an the output voltage at output terminal. The exact design of a control circuit, to achieve the desired regulation, is well known in the art and hence is not disclosed in detail herein. This control circuit 350 is suitable for application to the converters of FIGS. 5, 6, 7 and 8.

A modified version of the circuit of FIG. 3 is shown in the circuit schematic of the FIG. 5. The converter of FIG. 5 is a clamped mode forward converter having two gated synchronous rectifying devices 105 and 106. In this embodiment of the synchronous rectifier the synchronized rectifying device 106 can be used without adversely affecting the converter efficiency at lower operating frequencies.

The circuit of FIG. 6 is a clamped mode forward converter 20 having a rectifier analogous to that of FIG. 3 in using one bipolar rectifying diode. The secondary winding is tapped creating two secondary winding segments 603 and 602.

The converter of FIG. 7 operates in a flyback mode. The bipolar and synchronous rectifier device are in a reversed 25 connection from the connection of FIG. 3 to accommodate the flyback operation.

In some applications direct application of the gate drive signal directly from the secondary winding may result in 30 voltage spikes exceeding the rating of the gate. A small signal MOSFET device 813 is connected to couple the gate drive to the MOSFET rectifying device 105. This device may be controlled by the control drive lead 815 to limit the peak voltage applied to the gate of rectifier 105. The MOSFET synchronous rectifier is then discharged through 35 the body diode of the MOSFET device 813.

- iii:
- in a power converter, comprising:
    - an input for accepting a DC voltage;
    - a power transformer including a primary and secondary winding;
    - a power switch for periodically connecting the input to the primary winding;
    - an output for accepting a load to be energized;
    - clamping means for limiting a voltage and extending the voltage's duration across the secondary winding at a substantially constant amplitude during substantially an entire extent of a clamping interval of a cyclic period of the power converter;
  - a rectifier circuit connecting the secondary winding to the output; and including:
    - a synchronous rectification device with a control terminal connected to be responsive to a signal across the secondary winding such that the synchronous rectification device conducts a load current during substantially the entire extent of the clamping interval; and
    - a rectifying device connected for enabling conduction of the load current during a second interval other than the clamping interval.
2. In a power converter, comprising
- an input for accepting a DC voltage;
  - a power transformer including a primary and secondary winding;
  - a power switch for periodically connecting the input to the primary winding during a second interval of a cyclic period;
  - an output for accepting a load to be energized;
  - clamping means for limiting a voltage and extending the voltage's duration across the secondary winding at a substantially constant amplitude during substantially an entire extent of a clamping interval of a cyclic period of 5 the power converter;
  - a rectifier circuit connecting the secondary winding to the output; and including:
    - a first synchronous rectification device with a control terminal connected to be responsive to a signal 10 across the secondary winding such that the synchronous rectification device conducts a load current during substantially the entire extent of the clamping interval, and
    - a second synchronous rectification device with a control terminal connected to be responsive to a signal 15 across the secondary winding such that the second synchronous rectification device conducts the load current during substantially an entire extent of the 20 second interval other than the clamping interval.
3. In a power converter as claimed in claim 1 or 2, comprising:
- the converter connected to operate as a forward type converter.
4. In a power converter as claimed in claim 1 or 2, 25 comprising:
- the converter connected to operate as a flyback type converter.
5. A switching mode power converter, comprising: 30
- a power transformer including a magnetizing inductance requiring periodic recycling;
  - a first power stage for converting a DC input into a periodic pulsed voltage applied to a primary winding of the transformer, including: 35
  - a clamping circuit for limiting a voltage of the transformer during the periodic recycling at a substantially constant amplitude and extending the voltage duration to maintain a constant voltage for substantially an entire extent of periodic recycling;

- second power stage for rectifying an output of a secondary winding of the transformer and applying it to a load to be energized, including:
- a synchronous rectifier including a first rectifying device with a control gate connected to be responsive to a signal across the secondary winding such that the synchronous rectification device conducts a load current during the periodic recycling when the clamping circuit is active, and
  - a second rectifying device connected for enabling conduction of the load current when the first rectifying device is nonconducting.
6. A switching mode power converter as claimed in claim 5, further comprising:
- the second rectifying device comprises a diode.
7. A switching mode power converter as claimed in claim 5, further comprising:
- the second rectifying device comprises a rectifying device with a control gate connected to be responsive to a signal of the secondary winding.
8. A switching mode power converter as claimed in claim 6 or 7, further comprising:
- the secondary winding tapped and separated into first and second winding segments, and the first rectifying device is connected to the first winding segment and the second rectifying device is connected to the second winding segment.
9. A switching mode power converter as claimed in claim 6 or 7, further comprising:
- the converter connected to operate as a forward type converter.
10. A switching mode power converter as claimed in claim 6 or 7, further comprising:
- the converter connected to operate as a flyback type converter.

Please add Claims 11-60:

11. A power converter, comprising:  
a power transformer having a plurality of windings;  
a clamping circuit, coupled to said power transformer, that limits a voltage across at least  
one of said plurality of windings during a clamping interval of said power converter; and  
a synchronous rectification device coupled to said power transformer and having a control  
terminal responsive to a signal across at least one of said plurality of windings such that said  
synchronous rectification device is active for substantially all of said clamping interval.
12. The power converter as claimed in claim 11 wherein said clamping circuit is  
directly connected to said power transformer.
13. The power converter as claimed in claim 11 wherein said clamping circuit is  
coupled to a primary winding of said power transformer.
14. The power converter as claimed in claim 11 wherein said power transformer has a  
center-tapped secondary winding.
15. The power converter as claimed in claim 11 further comprising a power switch  
that connects a primary winding of said power transformer to an input of said power converter  
during a first cyclic interval of said power converter.
16. The power converter as claimed in claim 11 further comprising a further  
synchronous rectification device, coupled to said power transformer, that is active during a first  
cyclic interval of said power converter.
17. The power converter as claimed in claim 11 further comprising a rectification  
device, coupled to said power transformer, that is active during a first cyclic interval of said  
power converter.
18. The power converter as claimed in claim 11 wherein said clamping circuit  
comprises a switching device connected in series with a capacitor.
19. The power converter as claimed in claim 18 further comprising a control circuit  
that controls said switching device.
20. The power converter as claimed in claim 11 wherein said power converter operates  
in one of:  
a forward mode,  
a flyback mode, and  
a forward/flyback mode.

21. A power converter, comprising:  
a power transformer having a plurality of windings;  
a synchronous rectification device coupled to at least one of said plurality of windings and  
having a control terminal; and  
a clamping circuit, coupled to said power transformer, that limits a voltage applied to said  
control terminal such that said synchronous rectification device is active for substantially all of a  
clamping interval.
22. The power converter as claimed in claim 21 wherein said clamping circuit is  
directly connected to said power transformer.
23. The power converter as claimed in claim 21 wherein said clamping circuit is  
coupled to a primary winding of said power transformer.
24. The power converter as claimed in claim 21 wherein said power transformer has a  
center-tapped secondary winding.
25. The power converter as claimed in claim 21 further comprising a power switch  
that connects a primary winding of said power transformer to an input of said power converter  
during a first cyclic interval of said power converter.
26. The power converter as claimed in claim 21 further comprising a further  
synchronous rectification device, coupled to said power transformer, that is active during a first  
cyclic interval of said power converter.
27. The power converter as claimed in claim 21 further comprising a rectification  
device, coupled to said power transformer, that is active during a first cyclic interval of said  
power converter.
28. The power converter as claimed in claim 21 wherein said clamping circuit  
comprises a switching device connected in series with a capacitor.
29. The power converter as claimed in claim 28 further comprising a control circuit  
that controls said switching device.
30. The power converter as claimed in claim 21 wherein said power converter operates  
in one of:  
a forward mode,  
a flyback mode, and  
a forward/flyback mode.

31. A power converter, comprising:  
a power transformer having a plurality of windings;  
a synchronous rectification device having a control terminal and coupled to at least one of  
said plurality of windings; and

a clamping circuit, coupled to said power transformer, that limits a voltage applied to said  
control terminal such that said synchronous rectification device conducts a load current for  
substantially all of a clamping interval.

32. The power converter as claimed in claim 31 wherein said clamping circuit is  
directly connected to said power transformer.

33. The power converter as claimed in claim 31 wherein said clamping circuit is  
coupled to a primary winding of said power transformer.

34. The power converter as claimed in claim 31 wherein said power transformer has a  
center-tapped secondary winding.

35. The power converter as claimed in claim 31 further comprising a power switch  
that connects a primary winding of said power transformer to an input of said power converter  
during a first cyclic interval of said power converter.

36. The power converter as claimed in claim 31 further comprising a further  
synchronous rectification device, coupled to said power transformer, that is active during a first  
cyclic interval of said power converter.

37. The power converter as claimed in claim 31 further comprising a rectification  
device, coupled to said power transformer, that is active during a first cyclic interval of said  
power converter.

38. The power converter as claimed in claim 31 wherein said clamping circuit  
comprises a switching device connected in series with a capacitor.

39. The power converter as claimed in claim 37 further comprising a control circuit  
that controls said switching device.

40. The power converter as claimed in claim 31 wherein said power converter operates  
in one of:  
a forward mode,  
a flyback mode, and  
a forward/flyback mode.

41. A power converter, comprising:  
a power transformer having a plurality of windings;  
a synchronous rectification device having a control terminal responsive to a drive signal  
and coupled to at least one of said plurality of windings; and  
a clamping circuit, coupled to said power transformer, that limits said drive signal applied  
to said control terminal such that said drive signal is continuous for substantially all of a clamping  
interval.
42. The power converter as claimed in claim 41 wherein said clamping circuit is  
directly connected to said power transformer.
43. The power converter as claimed in claim 41 wherein said clamping circuit is  
coupled to a primary winding of said power transformer.
44. The power converter as claimed in claim 41 wherein said power transformer has a  
center-tapped secondary winding.
45. The power converter as claimed in claim 41 further comprising a power switch  
that connects a primary winding of said power transformer to an input of said power converter  
during a first cyclic interval of said power converter.
46. The power converter as claimed in claim 41 further comprising a further  
synchronous rectification device, coupled to said power transformer, that is active during a first  
cyclic interval of said power converter.
47. The power converter as claimed in claim 41 further comprising a rectification  
device, coupled to said power transformer, that is active during a first cyclic interval of said  
power converter.
48. The power converter as claimed in claim 41 wherein said clamping circuit  
comprises a switching device connected in series with a capacitor.
49. The power converter as claimed in claim 48 further comprising a control circuit  
that controls said switching device.
50. The power converter as claimed in claim 41 wherein said power converter operates  
in one of:  
a forward mode,  
a flyback mode, and  
a forward/flyback mode.

51. A power converter, comprising:  
an input that accepts a DC voltage;  
an output that provides current to a load;  
a power transformer having at least one primary winding and at least one secondary  
winding;  
a power switch that periodically connects said input to said at least one primary winding  
during a first cyclic interval of said power converter;  
a clamping circuit that limits a voltage across said at least one secondary winding during a  
clamping interval of said power converter; and  
a synchronous rectification device having a control terminal responsive to a signal across  
said at least one secondary winding such that said synchronous rectification device is active for  
substantially all of said clamping interval.

52. The power converter as claimed in claim 51 wherein said clamping circuit is  
directly connected to said power transformer.

53. The power converter as claimed in claim 51 wherein said clamping circuit is  
coupled to said at least one primary winding of said power transformer.

54. The power converter as claimed in claim 51 wherein said at least one secondary  
winding has a center-tap.

55. The power converter as claimed in claim 51 further comprising a voltage limiting  
device coupled to said synchronous rectification device.

56. The power converter as claimed in claim 51 further comprising a further  
synchronous rectification device, coupled to said power transformer, that is active during a first  
cyclic interval of said power converter.

57. The power converter as claimed in claim 51 further comprising a rectification  
device, coupled to said power transformer, that is active during a first cyclic interval of said  
power converter.

58. The power converter as claimed in claim 51 wherein said clamping circuit  
comprises a switching device connected in series with a capacitor.

59. The power converter as claimed in claim 58 further comprising a control circuit  
that controls said switching device.

60. The power converter as claimed in claim 51 wherein said power converter operates  
in one of:  
a forward mode,  
a flyback mode, and  
a forward/flyback mode.

## ABSTRACT

A synchronous rectifier for use with a clamped-mode power converter uses in one embodiment a hybrid rectifier with a MOSFET rectifying device active in one first cyclic interval of the conduction/nonconduction sequence of the power switch and a second rectifying device embodied in one illustrative embodiment as a low voltage bipolar diode rectifying device active during an alternative interval to the first conduction/nonconduction interval. The gate drive to the MOSFET device is continuous at a constant level for substantially all of the second interval which enhances efficiency of the rectifier. The bipolar rectifier device may also be embodied as a MOSFET device. The subject rectifier may be used in both forward and flyback power converters.

FIG. 1

(PRIORITY ART)

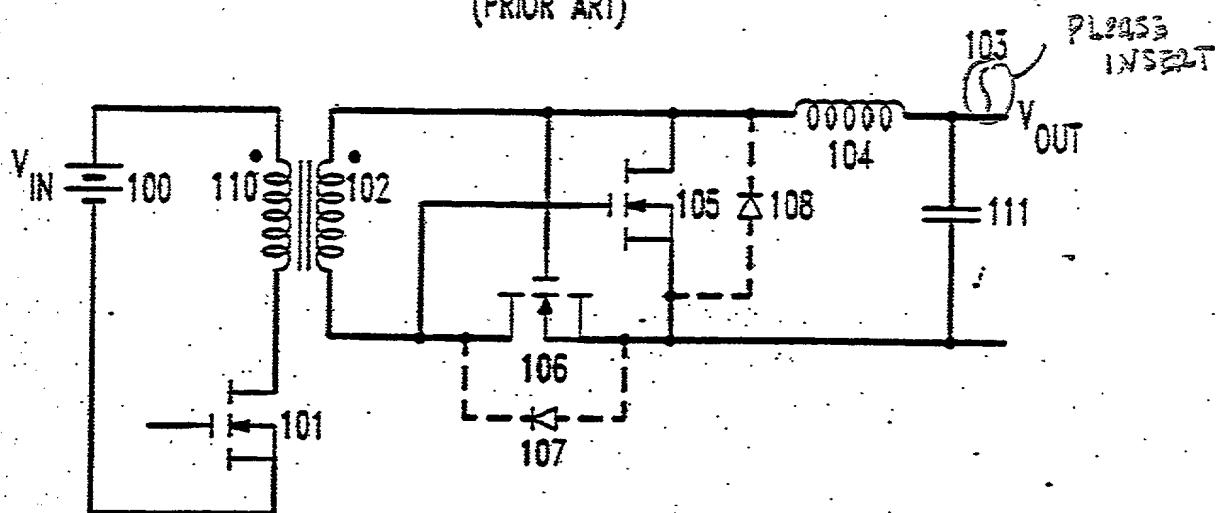


FIG. 2

(PRIOR ART)

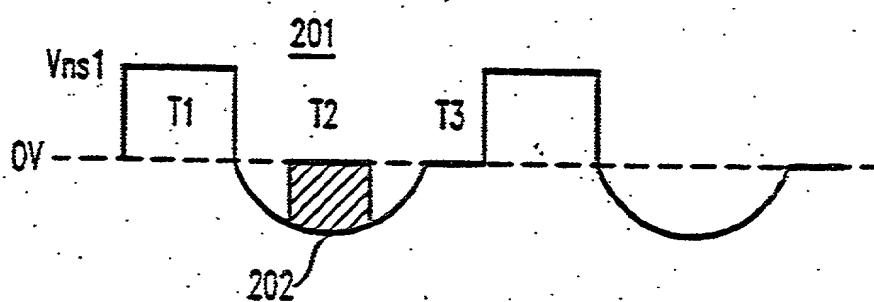


FIG. 3

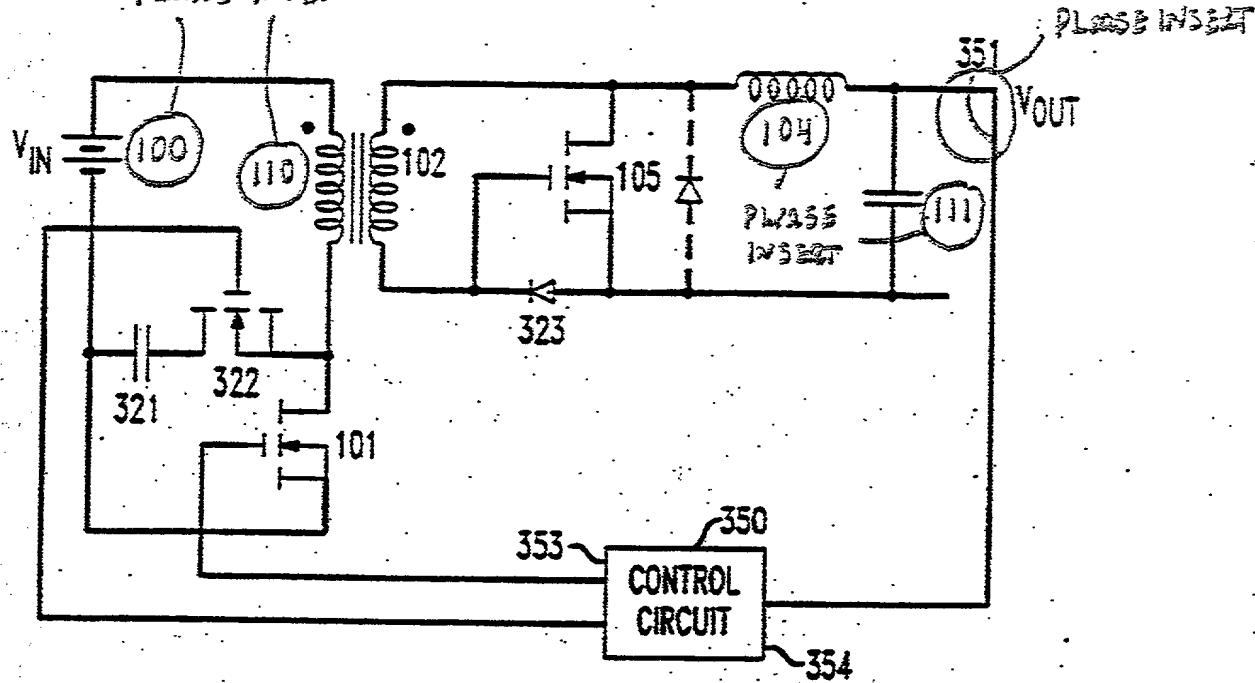


FIG. 4

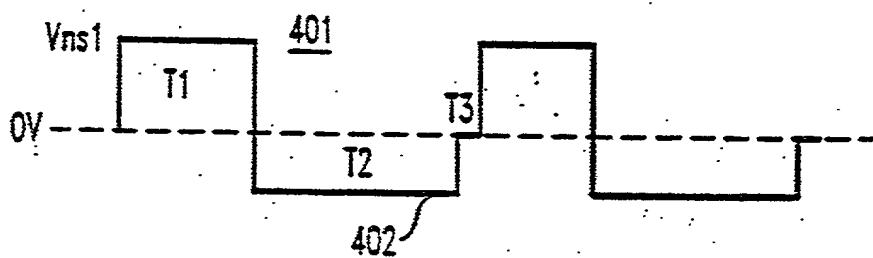


FIG. 5

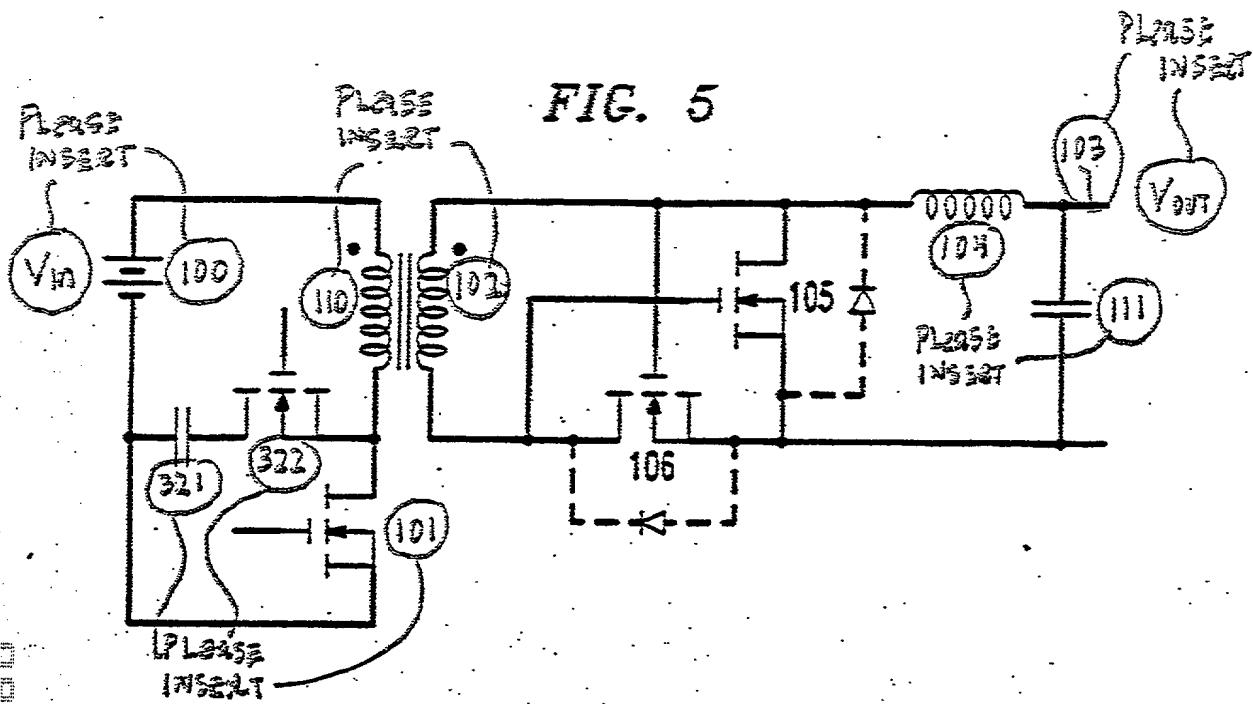
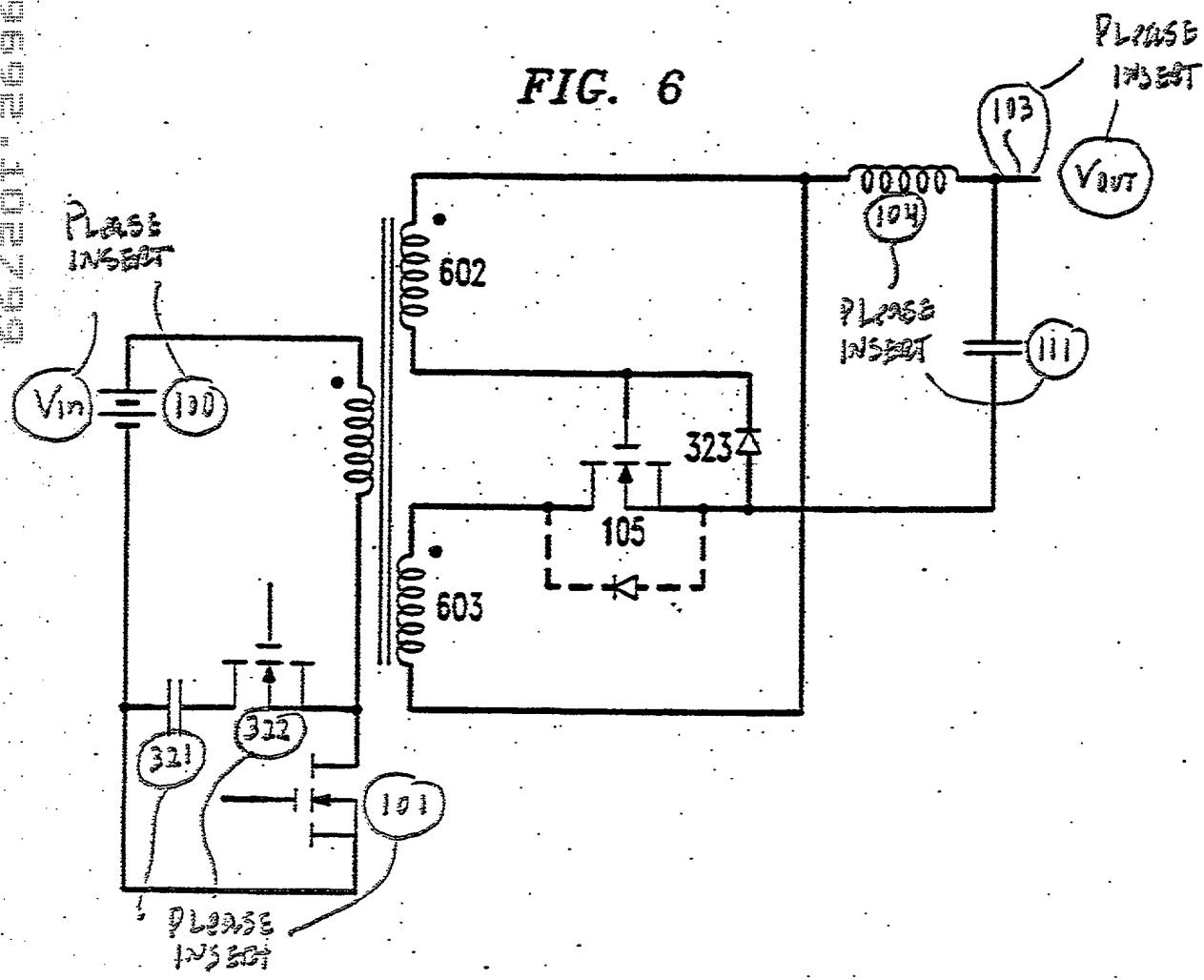
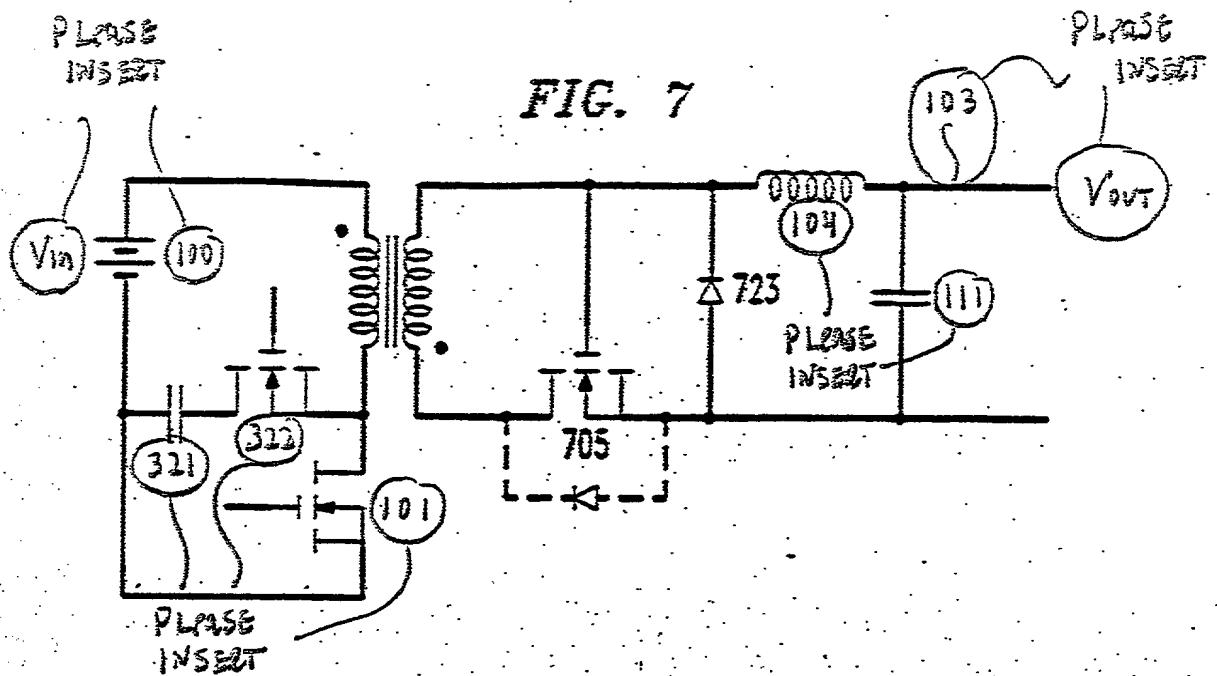
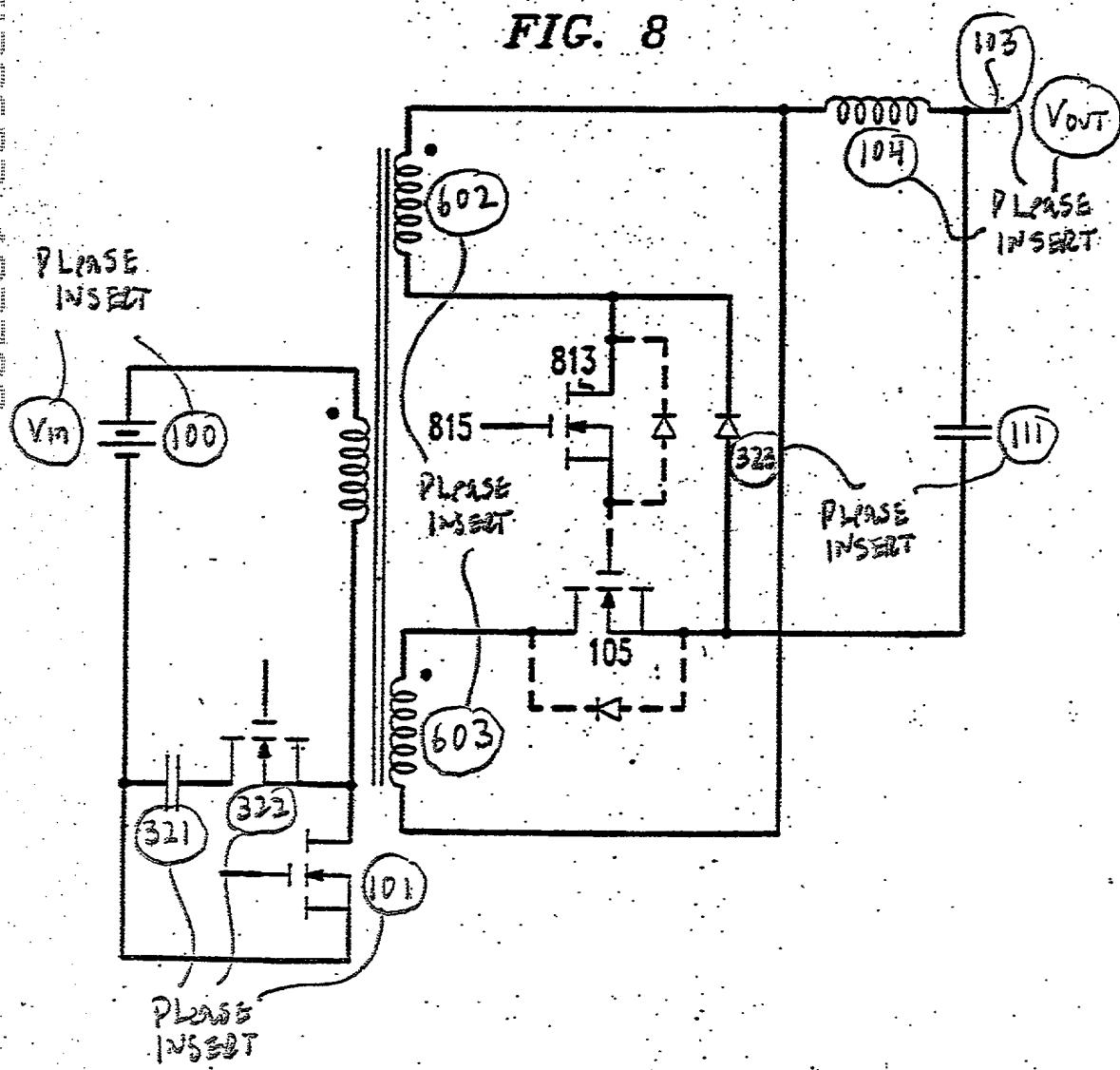
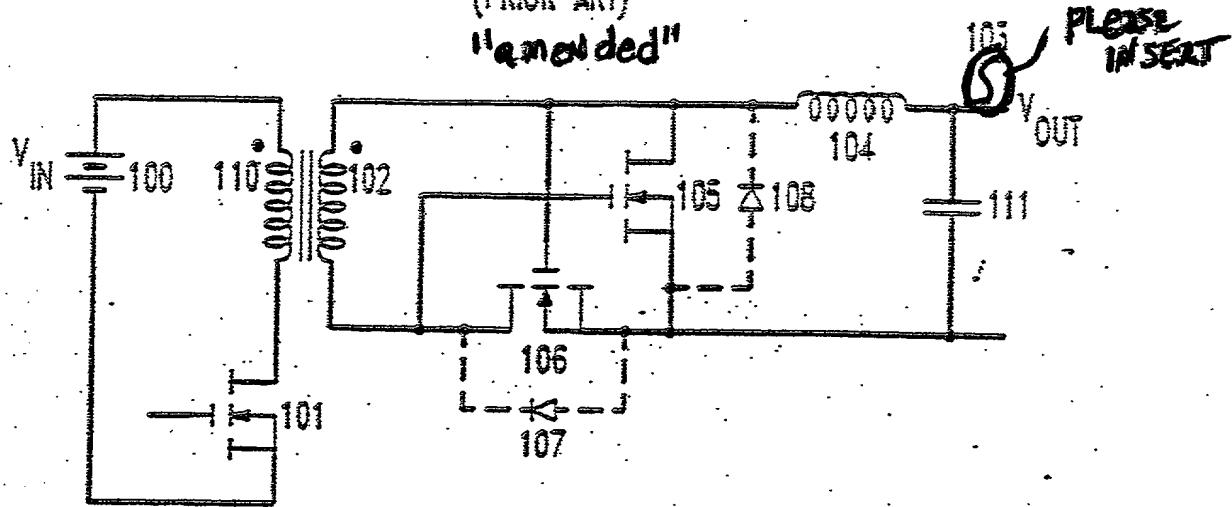


FIG. 6

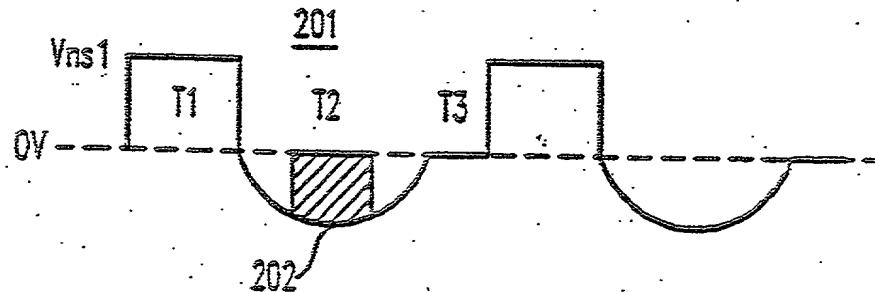


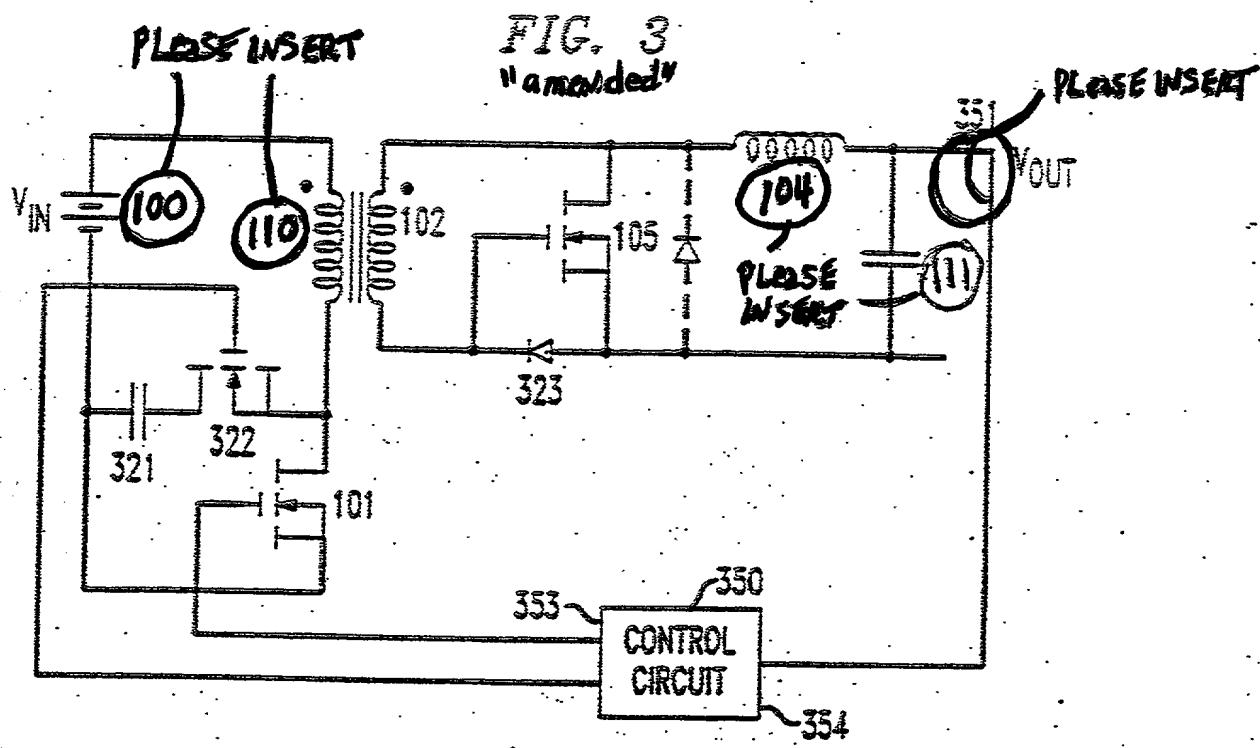
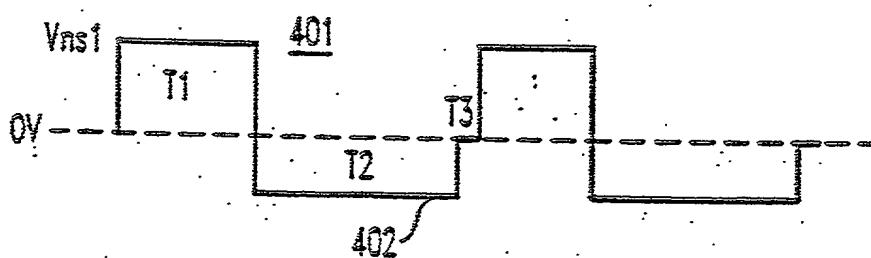
**FIG. 8**

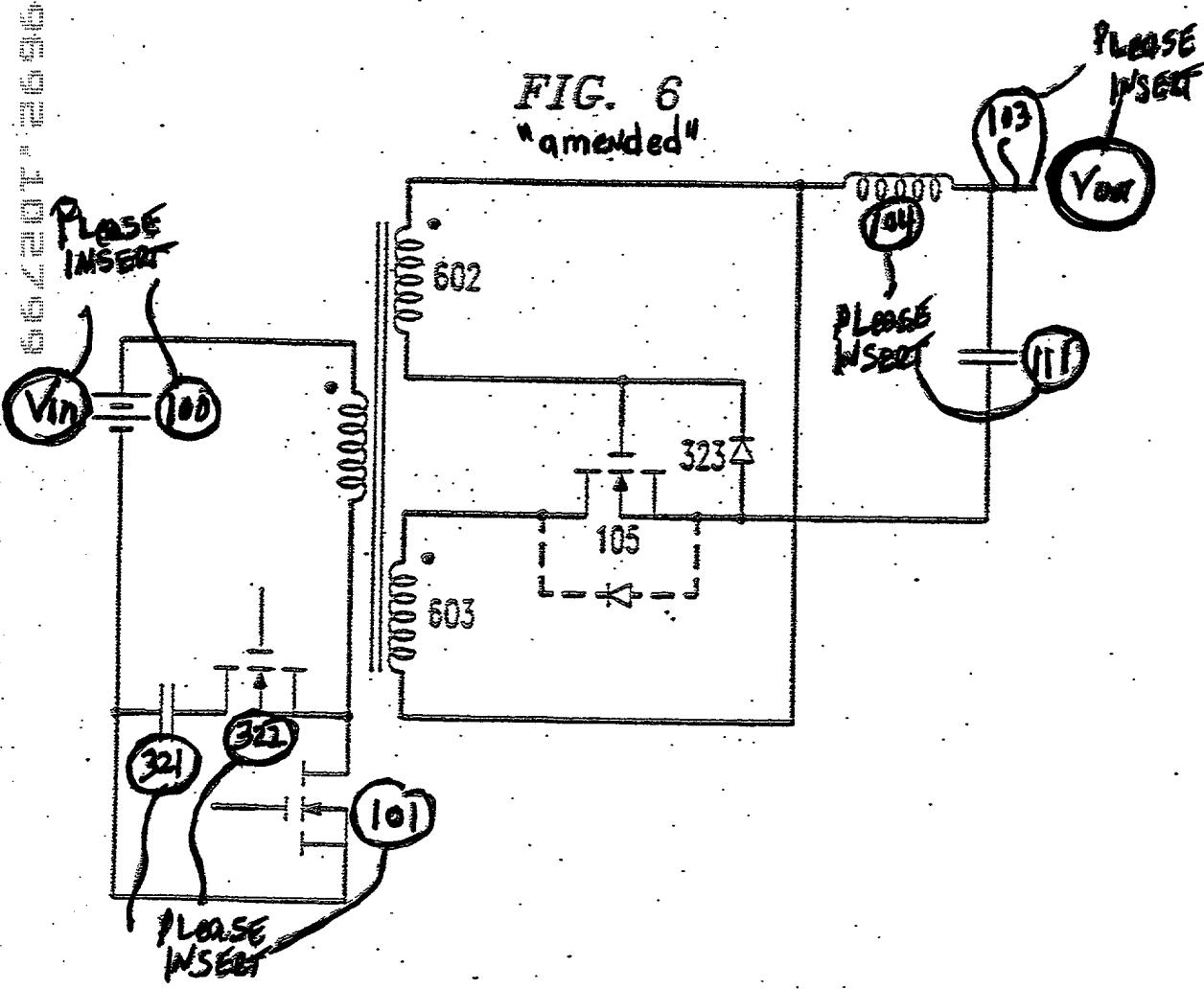
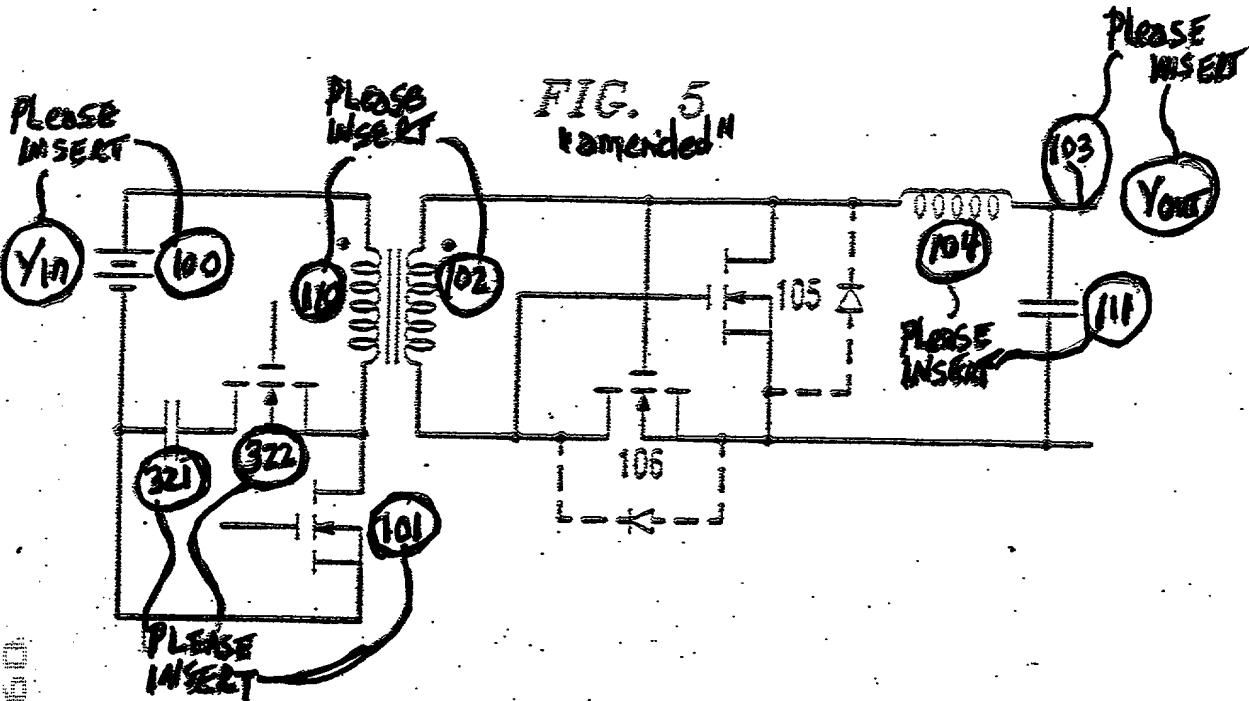
**FIG. 1**  
**(PRIOR ART)**  
**"Amended"**

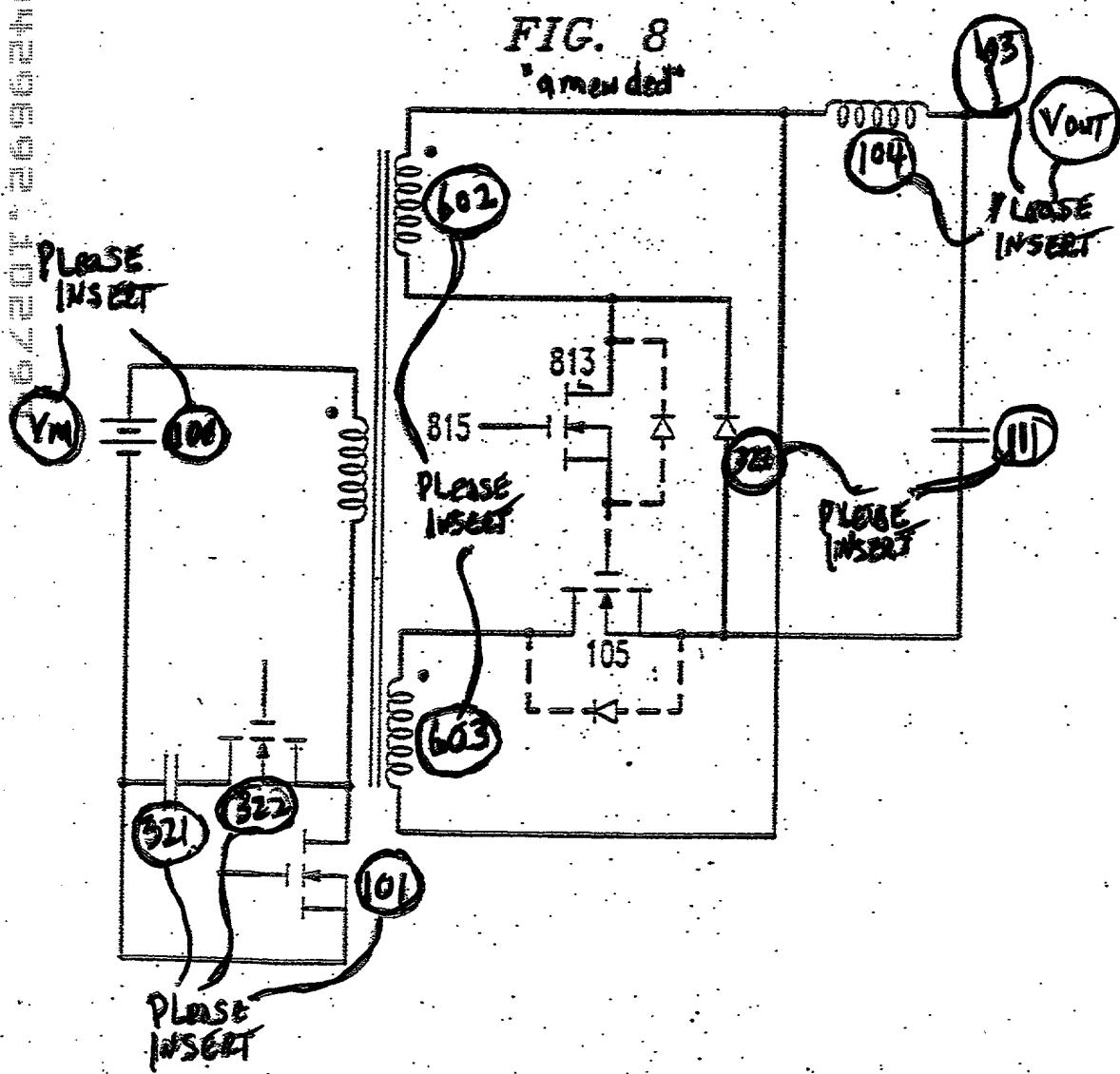
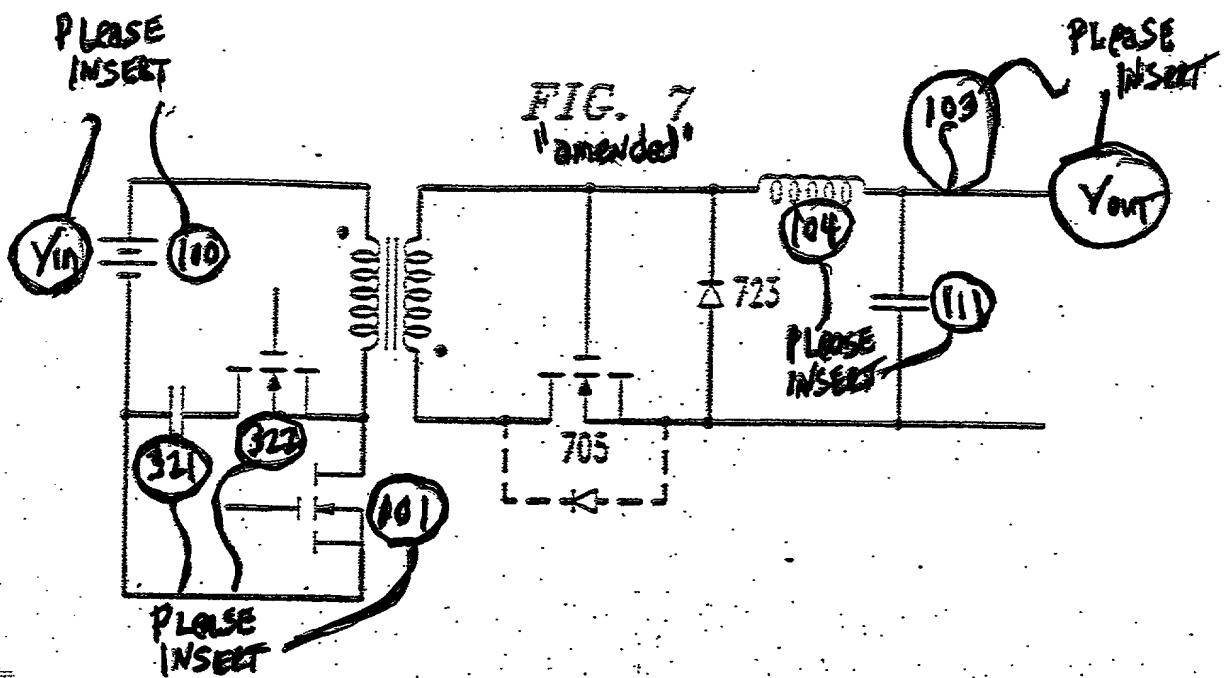


**FIG. 2**  
**(PRIOR ART)**



**FIG. 4**





Atty. Docket No. ROZMAN 30RE

PATENT

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

**CONTINUATION REISSUE APPLICATION**

of U.S. Patent Application Serial No.: 09/039,106

Applicant: Allen Frank Rozman

Title: Low Loss Synchronous Rectifier for Application to  
Clamped-Mode Power Converters

**DECLARATION**

Honorable Commissioner of Patents and Trademarks  
Washington, D.C. 20231

Box: Reissue

Sir:

As the below named inventor, I hereby declare that my residence, post office address and citizenship are as stated below next to my name and that I believe that I am the original and first inventor of the subject matter which is described and claimed in U.S. Patent Application Serial No. 09/039,106, which is a reissue application of U.S. Patent No. 5,528,482, granted June 18, 1996, and for which a continuation reissue patent is sought on the invention entitled: "Low Loss Synchronous Rectifier for Application to Clamped-Mode Power Converters," the specification of which is attached hereto.

I have reviewed and understand the contents of the above identified specification, including the claims.

I acknowledge the duty to disclose information that is material to the examination of this application in accordance with 37 C.F.R. §1.56.

New independent Claims 61, 71, 81, 91 and 101, as introduced in the continuation reissue application, are presented for matter originally shown or described, but not substantially embraced in the statement of invention or claims originally presented. The new claims do not introduce new matter since the specification, which has not been changed, directly supports the new claims.

New Claims 62-70, 72-80, 82-90, 92-100 and 102-110, as presented in the continuation reissue application, are dependent on new independent Claims 61, 71, 81, 91 and 101, respectively, and therefore include the limitations of the new independent Claims. No new matter is introduced.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application, or any patent issuing thereon, or any patent to which this declaration is directed.

Full name of inventor: Allen Frank Rozman

Residence and Post Office Address:

1702 Waverly Court  
Richardson, Texas 75082

Citizenship: United States of America

Inventor's signature: Allen Frank Rozman

Date: 10-24-99

Atty. Docket No. ROZMAN 6

PATENT

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

**REISSUE APPLICATION**

U.S. Patent No.: 5,528,482

Issued: June 18, 1996

Applicant: Allen Frank Rozman

Title: Low Loss Synchronous Rectifier for Application to Clamped-Mode Power Converters

**DECLARATION**

Honorable Commissioner of Patents and Trademarks  
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Sir:

As the below named inventor, I hereby declare that my residence, post office address and citizenship are as stated below next to my name and that I believe that I am the original and first inventor of the subject matter which is described and claimed in the U.S. Patent No. 5,528,482, granted June 18, 1996, and for which a reissue patent is sought on the invention entitled: "Low Loss Synchronous Rectifier for Application to Clamped-Mode Power Converters," the specification of which is attached hereto.

I have reviewed and understand the contents of the above identified specification, including the claims.

I acknowledge the duty to disclose information that is material to the examination of this application in accordance with 37 C.F.R. §1.56.

I believe that the original patent is wholly or partly inoperative or invalid by reason of a defective declaration and that the error arose without any deceptive intention. The declaration was defective on its face since the application was inadvertently identified as a continuation-in-part rather than a continuation.

I further believe that the original patent is wholly or partly inoperative or invalid by reason of defective drawings and that the errors arose without any deceptive intention. More specifically, reference numerals were inadvertently omitted from several figures. The specification clearly supports the addition of the reference numerals and no new matter is introduced. The corrections are indicated in the drawings submitted in the reissue application.

I further believe that the original patent is wholly or partly inoperative by reason of claiming less than I had the right to claim in the patent and that the error arose without any deceptive intention. I believe that the scope of Claims 1-10 is unnecessarily narrow in light of what is disclosed in U.S. Patent Number 5,528,482.

New independent Claims 11, 21, 31, 41 and 51, as presented in the reissue application, are broader in scope. The new claims more particularly point out and distinctly claim the invention in U.S. Patent Number 5,528,482. The new claims do not introduce new matter since the specification, which has not been changed, directly supports the new claims.

New Claims 12-20, 22-30, 32-40, 42-50 and 52-60, as presented in the reissue application, are dependent on new independent Claims 11, 21, 31, 41 and 51, and therefore include the limitations of the new independent Claims. No new matter is introduced.

All the errors corrected in this reissue application arose without any deceptive intention on my part.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application, or any patent issuing thereon, or any patent to which this declaration is directed.

Full name of inventor: Allen Frank Rozman

Residence and Post Office Address:

1702 Waverly Court  
Richardson, Texas 75082

Citizenship: United States of America

Inventor's signature: Allen F. Rozman Date: 3-12-98